INFLUENCE OF CERTAIN SMALL QUANTITIES OF 2,4-D ON BANANAS

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ABSTRACT

In efforts to determine the influences of small quantities of 2,4-D on bananas, 2.6, 5.1, 10.8, 10.8, 10.8, and 104.0 parts-per-million dilutions were sprayed on foliage, stem, and fruit surfaces of 50 clumps of the Cavendish (Chinese) variety at a rate of 0.6, 1.6, 11.2, 11.2, 11.2, and 91.8 grams, respectively, of 2,4-D acid per acre. The first two dosages (2.6 and 5.1 ppm dilutions applied at a rate of 0.6 and 1.6 grams acid per acre) were sufficient to produce symptoms on sensitive plants of the same degree of severity as those found on an assortment of plants grown in close proximity to certain sites of extensive 2,4-D usage. The tests were made in the Kahuluu valley, Oahu, on vigorous, uniform Cavendish bananas. Care was exercised in preventing 2,4-D from drifting into the untreated portion of the field.

Applications of 2.6 (0.6 gram per acre) and 5.1 (1.6 grams per acre) ppm solutions of 2,4-D produced no detectable response among bananas. Neither did a first application of a 10.8 ppm solution (11.2 grams per acre) induce a response. When a second 10.8 ppm application was made, however, midvein russeting occurred, a condition that was further intensified by additional applications of this amount of 2,4-D. Plant growth, yield, and rate of maturity of bunches were unaffected.

When 2,4-D was applied to bananas at a rate of 91.8 grams of acid per acre in a 104 ppm dilution, midvein russeting, pseudostem buckling and cracking, sucker distortion, fruit disfigurement, finger contortion, hastened ripening, increased stalk fragility, lowered yield, and increased sucker formation occurred. These factors resulted in (1) the death or destruction of 89 percent of the sprayed plants and 31 percent of the suckers developing during the first 2 months after treatment; (2) the destruction of 86 percent of the sprayed fruit; (3) the production of only five new bunches during the first 8 months after treatment; (4) with the exception of six bunches harvested immediately after treatment, the harvest of no new bunches until the end of the 11th month after treatment; and (5) although increased sucker production followed the application of 104 ppm 2,4-D, they were considered undesirable for propagation purposes for the first 3 months after treatment. Suckers emerging more than 90 days after treatment appeared to be equal in all respects to suckers arising from untreated clumps.

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INTRODUCTION

When the herbicidal properties of 2,4-Dichlorophenoxyacetic acid (hereinafter abbreviated 2,4-D) became known a few years ago, wide interest was shown in the utilization of this material in a variety of agricultural operations in Hawaii. At that time, the volatility factors possessed by certain formulations of 2,4-D (i.e., ester), the ability of 2,4-D to be easily and widely disseminated by wind, and the ability of 2,4-D to contaminate farm machinery and agricultural chemicals were not fully realized. Consequently, as weedicides containing this material were employed in sugarcane culture, pasture improvement, and lawn maintenance, many of the precautions now considered essential in its safe utilization were not necessarily observed. As a result, the fumes and dust of 2,4-D often drifted to untreated areas, affecting an assortment of economic and wayside plants, both in close proximity to the site of application and at distances often some miles away. The extent of injury varied from no discernible symptoms on some plants to conspicuous symptoms on others.

For the most part, no difficulty was involved in identifying symptoms induced on dicotyledonous plants by 2,4-D, once such symptoms became familiar. In the case of the banana, however, much confusion arose. Unlike other broad-leaved plants, the banana, when observed to respond at all, did so in a manner unfamiliar to banana growers or in a manner dissimilar to anything previously ascribed by the literature to 2,4-D. This led to conflicting ideas on the cause of certain abnormalities reported on bananas grown both within and away from areas known or suspected of having received 2,4-D. Likewise, disagreement arose as to the degree of sensitivity of this crop and how much 2,4-D would be required to bring about noticeable plant and fruit response.

Since bananas were grown extensively in both commercial and dooryard plantings in many of the agricultural areas where 2,4-D was being used or where its future use seemed likely, it was considered advisable to determine precisely the nature of the response of bananas to this substance and to determine the effects of certain small quantities of 2,4-D on their growth and yield. This bulletin presents the results of such determinations as were gathered and interpreted from controlled experiments.

MATERIALS AND METHODS

In initial phases of the experiment it was not known what quantities of 2,4-D would induce abnormalities in banana foliage or fruit or bring about certain of the responses reported from areas alleged to have been exposed to drifts of 2,4-D. As a starting point, therefore, various concentrations of this material were prepared and sprayed in various quantities over an assortment of sensitive plants in an attempt to duplicate the symptoms observed on wayside plants of the same species. Subsequent observations of these plants (tomatoes, beans, peppers, hibiscus, cotton, and papayas) revealed that when solutions containing between 2.5 and 5.0 ppm of 2,4-D were sprayed over the foliage in quantities representing the application of 0.75 to 1.50 grams of free 2,4-D acid per acre, symptoms of the same degree of intensity as those found among plants in areas adjacent to points of extensive 2,4-D usage could be approximated. Consequently, as a beginning in the determination of the reaction of bananas to 2,4-D, a 2.6 ppm solution was applied, followed by solutions of increasingly greater concentration, until a 10.8 ppm solution was administered. When no response to the latter was observed and when only a mild response to repeated applications of this concentration of 2,4-D was detected, the dosage was increased to 104 ppm.

2,4-D Used. In each application of 2,4-D, dilutions of Sharsol 193,[1] an amine concentrate containing 5 pounds of 2,4-D acid per gallon, were used. The strength of solution, amount of solution applied to each clump,[2] and the equivalent amount of 2,4-D applied per acre are given in table 1. In the first application (12–15–48) a 2.6 ppm solution, expressed as free-acid equivalent, was employed, while 5.1, 10.8, 10.8, 10.8, and 104.0 ppm solutions were used, respectively, in the 2–16–49, 7–7–49, 10–3–49, 10–12–49, and 12–5–49 tests. In the first and second applications, 300 cc. and 350 cc. of solution, respectively, were applied to each clump in the treated block. In subsequent applications, each clump received 1 liter (1,000 cc.) of solution. These dosage levels represent for the six tests, respectively, the application of 0.7, 1.6, 11.2, 11.2, 11.2, and 91.8 grams of 2,4-D acid per acre.

TABLE 1. Date, rate, and quantity of 2,4-D used in each of six applications

APPLICATION	DATE	STRENGTH	AMOUNT SOLUTION PER CLUMP	2,4-D ACID PER ACRE
		ppm	*cc.*	*gms.*
1.	12–15–48	2.6	300	0.67
2.	2–16–49	5.1	350	1.57
3.	7–7–49	10.8	1,000	11.24
4.	10–3–49	10.8	1,000	11.24
5.	10–12–49	10.8	1,000	11.24
6.	12–5–49	104.0	1,000	91.80

Time and Place of Experimentation. The tests were made in the Kahuluu valley, windward Oahu, where the chances of contaminating drifts of 2,4-D were considered negligible. Applications of the herbicide, starting in December, 1948, were made at intervals for approximately 1 year. The test plot (approximately 2 years old) comprised 220 Cavendish (Chinese) banana clumps spaced approximately 8 feet apart. At the outset, all clumps were healthy, vigorous, and uniform in size and appearance. A block of 150 clumps was selected for the test; 50 clumps were treated with 2,4-D and the remaining 100 were left untreated for control purposes. The untreated clumps, while in part surrounding the treated block, were in the main located to one side and adjacent to the treated block. A row of border clumps, not included in growth or yield observations, completely surrounded the experimental plot. The position of treated, untreated, and border trees is diagrammed in figure 1.

Methods of Application. The 2,4-D used in these tests was applied as a spray from a 3-gallon hand rig. The wetting agent Triton B–1956 was added to each tank of solution (0.45 gram per liter) to facilitate uniform wetting of leaf, stem, and

[1] This material was formulated by chemists at the Pacific Chemical and Fertilizer Company, Honolulu, and was donated for use in these experiments. The sample furnished was determined to have a specific gravity of 1.173.

[2] In many parts of the world the term "mat" is used in place of "clump." However, since the latter is well established in local vernacular, it will be used in this bulletin.

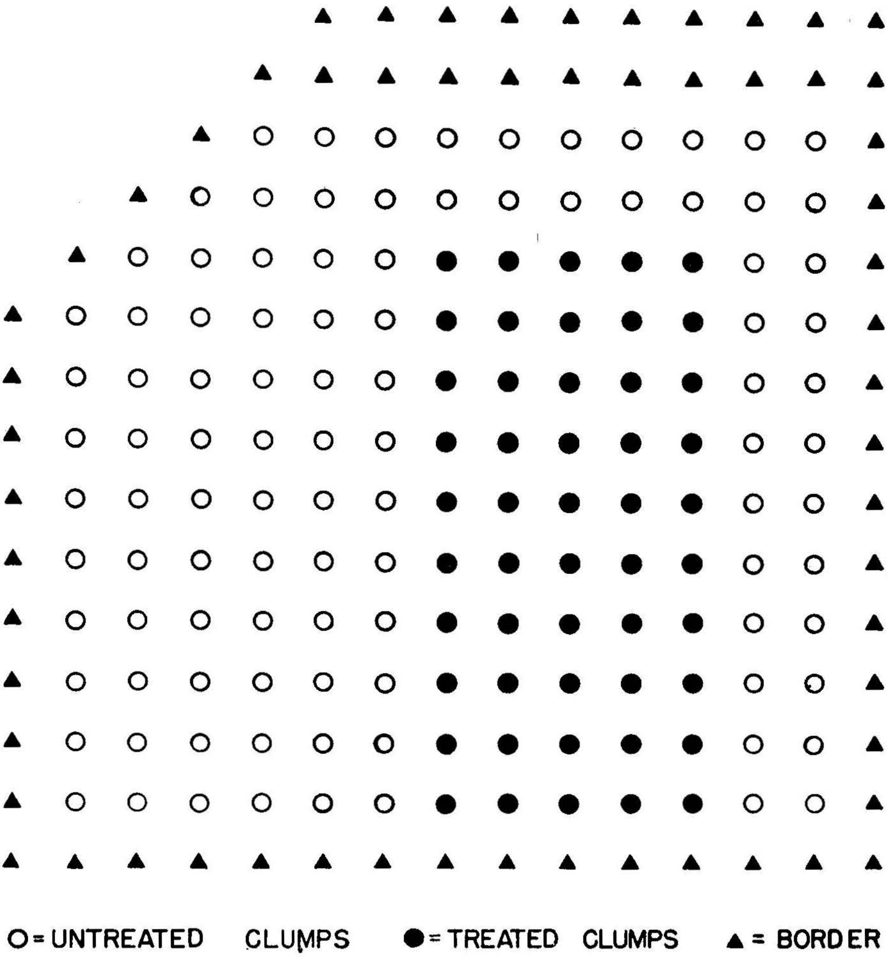

Fig. 1. The experimental plot, showing relative positions of treated, untreated, and border banana clumps.

fruit surfaces. Contamination of control trees was reduced by maintaining low tank pressure, by choosing days of low wind velocity, and by keeping constant control over spray drift. In addition, overlapping and interlocking leaves were separated before spraying to avoid contamination of leaves not intended to receive 2,4-D. To detect any drift of 2,4-D that might unavoidably reach the control area, potted plants of sensitive types (beans, cotton, and tomatoes) were interspersed among the banana plants prior to treatment. These were later removed to the greenhouse where they were cultured and observed for symptom development. At no time during the test were indicator plants interspersed among unsprayed trees observed to develop 2,4-D symptoms, suggesting the effectiveness of the above efforts in confining the spray to the treated portion of the field. On the other hand, all indicator plants interspersed among bananas in the treated plot developed 2,4-D symptoms, illustrating a uniform coverage of this area.

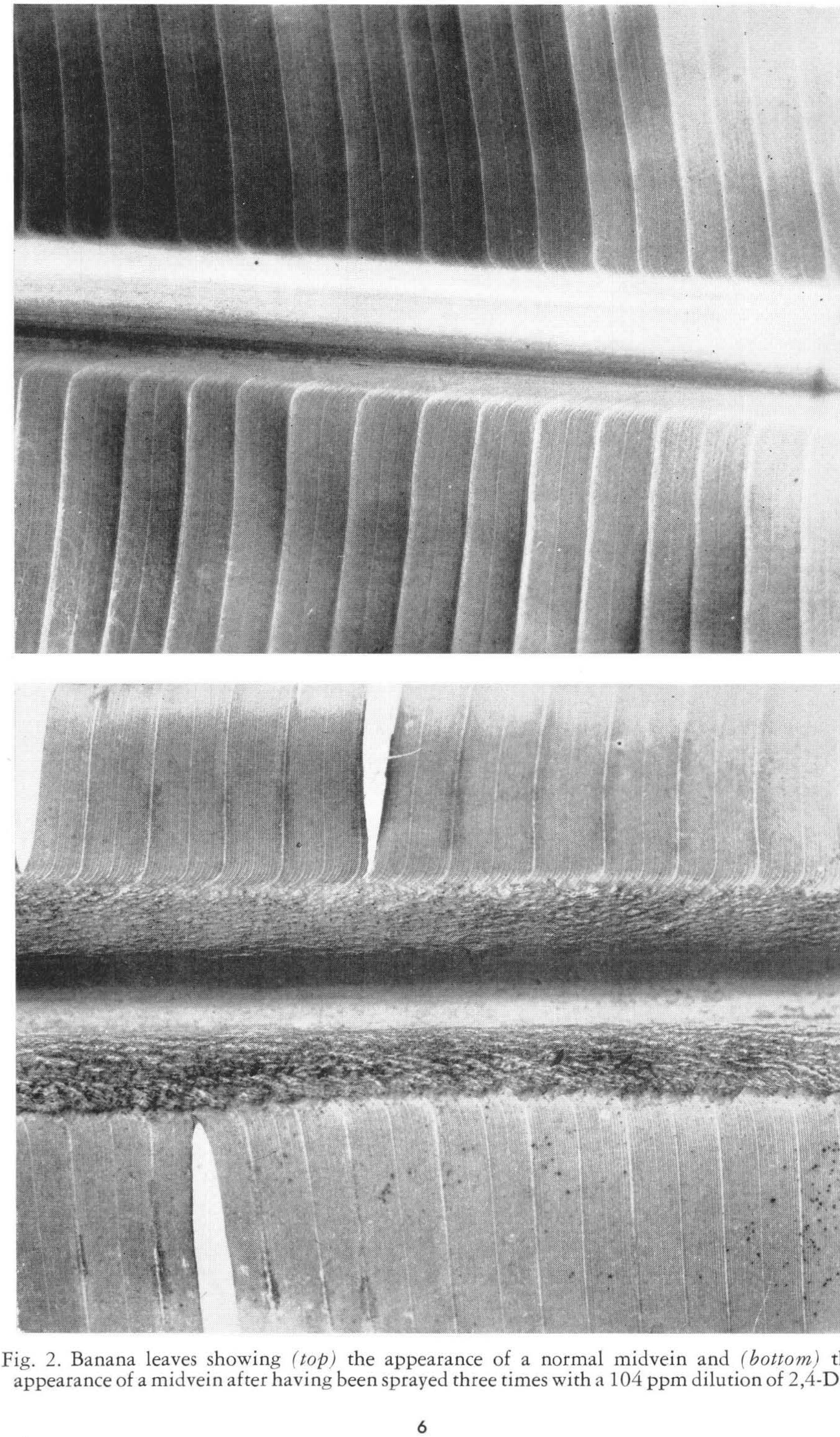

Fig. 2. Banana leaves showing *(top)* the appearance of a normal midvein and *(bottom)* the appearance of a midvein after having been sprayed three times with a 104 ppm dilution of 2,4-D.

RESULTS

Prior to the first application of 2,4-D, each clump in the experiment was carefully examined and determinations were made of tree height, diameter of bole, number of leaves per tree, number and position of suckers, and number and maturity of bunches. At frequent intervals following treatment the plot was re-examined, the emergence and harvest of bunches were recorded, and other aspects of individual trees were examined.

INFLUENCE OF 2,4-D UPON THE APPEARANCE OF BANANA FOLIAGE

Midvein Russeting. Although close attention was given to each banana plant in the experiment for approximately 6 months following the first and second applications of 2,4-D (2.6 and 5.1 ppm dilutions, respectively), no response whatever could be detected. Neither was there a detectable response to a first application of a 10.8 ppm dilution of this material. However, when 10.8 ppm 2,4-D was administered in two succeeding applications, a definite reaction was observed. This response became apparent shortly after the 10–3–49 application and became somewhat more apparent after the 10–12–50 application. The symptoms were almost entirely confined to ¼-inch bands paralleling the midveins on the top surfaces of sprayed leaves. Affected tissues in such bands were characterized by roughening and russeting of the surface and were located on one or both sides of the midrib. Figure 2 illustrates the appearance of this condition as compared to that of unaffected leaves. The affected portions did not always extend for the full length of the midrib although affected patches from 1 to 30 inches long were commonly observed at various points from the base of the petiole to the tip of the leaf.

Close scrutiny of all trees in the plot revealed that 100 percent of the treated plants had one or more affected leaves, while no single case of russeting existed among untreated trees.

Russeting of the type described also followed the use of 2,4-D of higher concentration, but, as will be discussed later, a high incidence of plant mortality masked the expression of this symptom. Midvein russeting appeared to be a response to direct contact with 2,4-D. At no time during the test were leaves of suckers emerging after treatment similarly affected.

INFLUENCE OF 2,4-D UPON MORTALITY AND PLANT DEFORMATION

Although midvein russeting was the only detectable response to 2,4-D concentrations of 10.8 ppm, an application of a 104.0 ppm solution of this material produced other definite effects. Among them were killing of plants, buckling and cracking of the pseudostems, and distortion of suckers. Fuller descriptions of these symptoms follow.

Pseudostem Buckling and Cracking. Beginning approximately 3 to 5 days after treatment, horizontal folds appeared at and slightly above the soil line on the outer sheaths of some pseudostems. This condition, illustrated in figure 3, *top,* was frequently followed and/or accompanied by vertical splitting or horizontal cracking of the pseudostem (fig. 3, *bottom*). When this occurred, splitting and cracking developed in the buckled region. When no buckling occurred, as was the case in a number of instances, splitting and cracking were, nevertheless, frequently observed. In these cases such symptoms developed at or near ground level and at no other point on the pseudostem.

These symptoms were confined principally to the boles of larger trees in existence at the time of treatment. However, numerous exceptions were found in which sprayed suckers, 15 to 30 inches tall, were similarly affected; suckers emerging after treatment were sometimes affected. Figure 4, *bottom,* illustrates both splitting and cracking of a pseudostem measuring 4½ inches in diameter at the

Fig. 3. *Top:* banana pseudostem showing horizontal buckling and vertical cracking of the outer sheaths. This condition, located near the ground line, was caused by a spray containing 104 ppm 2,4-D. *Bottom:* banana pseudostem showing horizontal cracking of the outer sheaths.

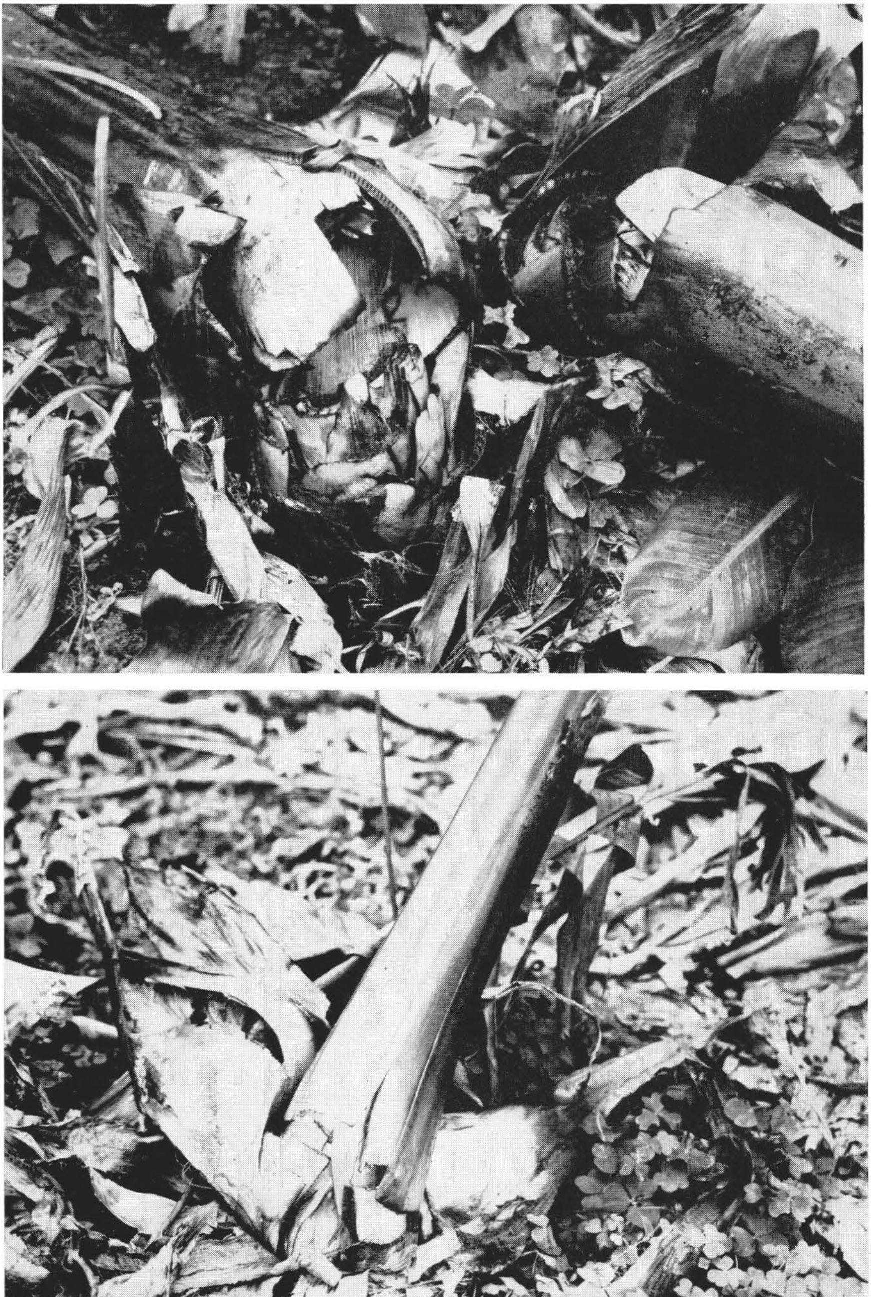

Fig. 4. *Top:* banana pseudostems with severe basal sheath cracking. These plants fell to the ground 14 days after application of a 104 ppm solution of 2,4-D. *Bottom:* cracking of pseudostem of sucker emerging after application of 104 ppm solution of 2,4-D.

base. Once started, the cracking process usually continued until the plant either toppled part way over and remained in a leaning position or toppled completely over and died. Figure 4, *top,* pictures two plants which succumbed in this manner. For the most part, the entire process of buckling, splitting, cracking, and toppling was completed within 8 weeks after treatment. In a few exceptions buckling and/or cracking occurred between the 8th and 10th week following treatment.

Notes made at frequent intervals during the course of study reveal that, at the time of treatment with 104 ppm 2,4-D solution, there were 109 trees and suckers in the sprayed portion of the plot. Of these, 60 (55 percent) toppled to the ground and died; 37 (34 percent) cracked and leaned so badly that they were removed in plot rehabilitation; 3 (3 percent) were severely cracked and leaning but were propped in an upright position until their bunches were harvested; and 9 (8 percent) remained unaffected except for the midvein russetting previously described.

As noted above, suckers emerging from the soil after the date of treatment were sometimes affected by 2,4-D. During the first 30 days following treatment, 135 new suckers emerged. Twenty-six of these (19 percent) died because of toppling; 24 (18 percent) were removed because of severe cracking and distortion; and 85 (63 percent) remained unaffected. Similar influences were also recorded on suckers emerging during the 2d month following treatment, although the effects were less severe. Out of 95 new suckers, 18 (19 percent) ultimately cracked and toppled; 3 (3 percent) plants were removed because of distortion; and 74 (78 percent) exhibited no signs of injury. By the end of the 3d month after treatment, carry-over effects of 2,4-D to emerging suckers were non-detectable.

Distortion of Suckers. In addition to buckling and cracking, a common response of young banana suckers to the heavier dose of 2,4-D (104 ppm) was distortion of leaves and stems. This condition, seen principally among suckers emerging subsequent to treatment, involved restriction of leaf development and distortion of the pseudostem. First evidence of distortion was usually observed in the crown of young suckers, where, on the average, the leaves attained a length and breadth of only about half that of untreated suckers (fig. 5, *left*). In more severe cases, leaf width was limited to 1½ to 3 inches (fig. 5, *right*), and leaf length was limited to about 16 inches. These conditions were accompanied by stiffening and coarsening of blade and midrib tissues. Midvein russeting, such as developed on plants which received direct applications of 2,4-D, was not evident on these plants.

Suckers with restricted leaf development were also often characterized (until they were approximately 4 feet high) by fewer leaves than normal. Whereas unaffected suckers of from 30 to 48 inches tall had eight or more leaves normally, it was rare to find more than four leaves on affected ones. After a height of 4 to 5 feet was attained, the tendency for fewer leaves was not apparent, although normal leaf size was never attained.

The more severely affected suckers — those arising during the first 4 weeks after treatment — usually cracked around the pseudostem base and died. Among less severe cases (in general those emerging between the 4th and 6th week after treatment) it was common to find leaf distortion, followed by bending of the pseudostem (fig. 5, *right*) or by separation of the leaf sheaths comprising the bole (fig. 6). Suckers showing decided curvature of the pseudostem were removed in plot rehabilitation. Therefore, their possible fate, had they been permitted to remain in the field, is not known. However, six plants of the types pictured in figure 6 were left undisturbed for further observation. These plants ultimately attained a height comparable to mature, unaffected trees but did not blossom. Instead, when vegetative maturity was reached (using cessation of growth as a measure of maturity), the leaves gradually died in acropetal succession.

Fig. 5. *Left:* distorted banana sucker showing smaller and fewer leaves than normal. *Right:* distorted suckers showing bending of the pseudostem as well as dwarfing of the leaves.

Fig. 6. A distorted banana tree resulting from treatment with 104 ppm solution of 2,4-D. Note the separation of sheaths from the pseudostem and the dwarfing of the foliage.

INFLUENCE OF 2,4-D ON APPEARANCE OF FRUIT IN THE FIELD

Earlier in this report it was pointed out that, within the treated portion of the plot, the fruit as well as the trunk and foliage of each tree was sprayed with 2,4-D. Solutions containing 2.6, 5.1, and 10.8 ppm, respectively, of 2,4-D brought about no detectable disfigurement of the fruit or hastening of ripening. The latter will be discussed more fully in a section on ripening. Repeated applications of 10.8 ppm 2,4-D were similiarly non-injurious. When a 104 ppm solution was applied, however, the results were quite different. Finger contortion, surface disfigurement, hastened ripening, and rotting occurred shortly after treatment. As evidenced by stalk breakage, there was also increased fragility in stalks of bunches emerging before or shortly after treatment. Fuller descriptions of these responses follow.

Surface Disfigurement. On the 4th day after treatment with the higher concentration (104 ppm) of 2,4-D, spotty watersoaking of fingers of many of the older bunches was observed. These areas later became darkened and by the 7th day most of the affected tissue had become noticeably roughened at the surface with a tendency for small horizontal and longitudinal cracks to develop in the affected portions. Accompanying these lesions were numerous localized swellings which gave a lumpy or warty appearance to the fruit (fig. 7). Individual swollen areas were not always associated with roughening or darkening of the peel although there was a tendency in that direction. The lumps or warts varied from the size of small peas to areas 1½ inches long and 1 inch across. Protrusion from the general plane of the fruit seldom exceeded $^{3}/_{16}$ inch. Cross sections through the swollen portions revealed no internal discoloration or other visible disturbance except in cases where swelling was associated with necrosis (roughening) of the surface. In such cases *Colletotrichum* sp. or some other disease agent gained entrance and sporulated.

Fig. 7. Hands of bananas showing disfigurement of the fingers resulting from an application of 104 ppm 2,4-D.

Fig. 8. Contortion of young banana fingers induced by 2,4-D. Note extreme curling, twisting, and elongation of fingers. Some fingers measured 14 inches in length.

Finger Contortion. Approximately 3 weeks after the final application of 2,4-D, the fingers on some bunches became very elongated, curled, and frequently twisted. This condition, referred to as finger contortion, involved six bunches and was confined to fruits of about 1 month of age at the time of treatment. None of the older bunches responded in this manner, and nothing suggestive of finger contortion was ever found in the untreated plot.

Influence on Rate of Maturity and Ripening. One of the controversial issues at the outset of the experiment was the influence of small quantities of 2,4-D on the rate of maturity of bananas in the field. In these tests no increase in the speed of maturity could be detected in fruits sprayed with 2.6, 5.1, or 10.8 ppm 2,4-D, or in fruits emerging after the application of these dosages. These conclusions are based on the fact that fruits sprayed with 2.6, 5.1, 10.8, and 10.8 ppm, respectively, required 62, 93, 120, and 126 days for maturity as compared with 60, 94, 117, and 127 days, respectively, for untreated fruit. These conclusions are further supported by the fact that fruits emerging after applications of 2.6, 5.1, and 10.8 ppm 2,4-D required 125, 121, and 127 days as compared to 123, 119, and 130 days, respectively, for the controls. These data are tabulated in table 2.

Fruits sprayed in the field with a 104 ppm solution of 2,4-D were observed to ripen soon after treatment. This applied to young, immature bunches as well as bunches approaching maturity. Although some of the fruits became disfigured or contorted before ripening, the internal tissues later ripened and the bunches rotted. The ripening and rotting process was complete within 8 weeks after treatment. Figure 9, *left,* shows a bunch badly rotted at the end of the 2d week after treatment and, *right,* the same bunch completely decomposed at the end of the 3d week after treatment. At the time of the 104 ppm application, 44 bunches were sprayed.

Of these, 38 (86 percent) ripened and rotted in the field and 6 (14 percent) were harvested before ripening and rotting were observed.

TABLE 2. Average number of days required for maturity of fruits treated with each of five applications of 2,4-D and fruits emerging after these applications

FRUIT CLASS	TREATED		UNTREATED	
	Number of bunches	Average days to maturity	Number of bunches	Average days to maturity
12-5-48 Application (2.6 ppm)				
Present at time of treatment*	39	62	59	60
Emerged after treatment	9	125	25	123
2-7-49 Application (5.1 ppm)				
Present at time of treatment*	31	93	59	94
Emerged after treatment	19	121	30	119
7-7-49 Application (10.8 ppm)				
Present at time of treatment	17	120	27	117
Emerged after treatment	16	127	34	130
10-3-49 and 10-12-49 applications (10.8 ppm)				
Present at time of treatment	20	126	39	127
Emerged after treatment	15	—	28	137
12-12-49 Application (104 ppm)				
Present at time of treatment	23	—	56	137
Emerged after treatment	5	—	78	128

*The shorter time requirements for maturity of the bunches present at the time of the 12-5-48 and 2-7-49 applications are explained by the fact that their date of emergence was unknown. Consequently, in these two lots of fruit, time requirements for maturity were dated from the time of treatment.

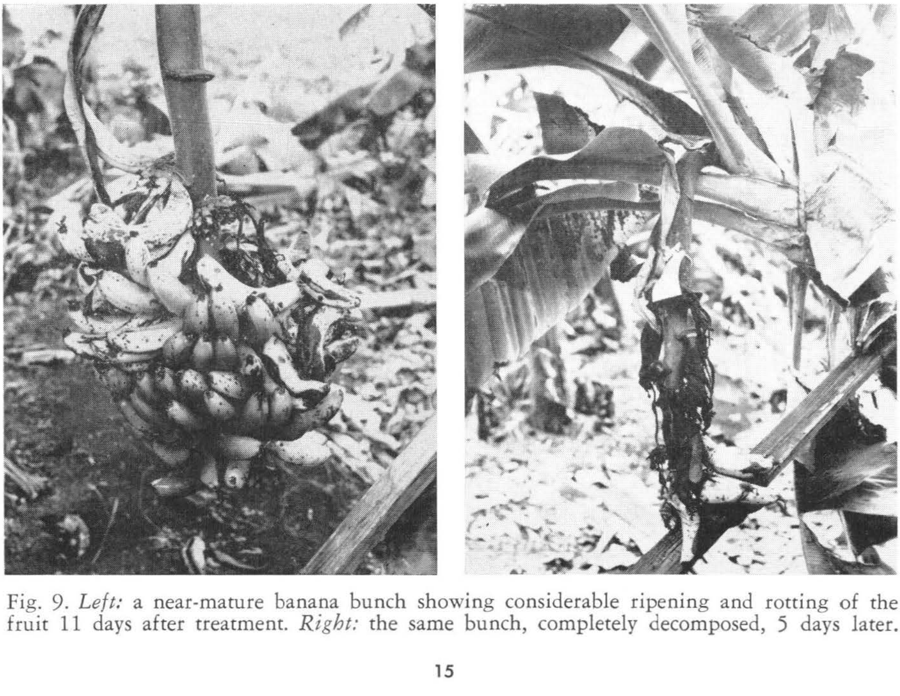

Fig. 9. *Left:* a near-mature banana bunch showing considerable ripening and rotting of the fruit 11 days after treatment. *Right:* the same bunch, completely decomposed, 5 days later.

Fig. 10. Young banana bunch having fallen from the tree under its own weight after receiving 2,4-D. Ninety-one grams of 2,4-D per acre was sufficient to induce stalk breakage.

Stalk Breakage. Two 3-week-old bunches broke from the tree 5 days after treatment, indicating that 104 ppm 2,4-D increased the fragility of stalks of young bunches. Similarly, two of the five bunches emerging after spraying (all within 8 days) broke from the pseudostem and fell to the ground (fig. 10). Observation of the stalks of these bunches revealed them to be quite brittle as compared to young stalks from unsprayed trees. Unfortunately, facilities were not available for measuring the degree to which treatment had increased fragility.

INFLUENCE OF 2,4-D ON GROWTH, YIELD, AND VEGETATIVE REPRODUCTION

Influence on Vigor. By determining the height of tree, rate of growth, number of leaves, and diameter of bole of each tree at the time of each application and at intervals following each application, it was possible to determine the influence of given doses of 2,4-D on the vigor of bananas. Table 3 gives the average heights of treated and untreated trees at intervals throughout the test. A comparison of these data reveals no essential difference between the two groups at the time of or following applications of 2.6, 5.1, 10.8, 10.8, and 10.8 ppm 2,4-D. However, following an application of 104 ppm, a 33 percent drop in the average height of treated trees was recorded. This situation, accounted for by the killing of many larger

TABLE 3. Average height of treated and untreated banana trees at intervals throughout the experiment

DATE	AVERAGE HEIGHT		DIFFERENCE IN HEIGHT
	Treated	Untreated	
			percent
12–13–48	38.4	38.1	+ 0.8
2–18–49	34.7	34.8	− 0.3
7–7–49	45.7	42.9	+ 6.5
9–12–49	57.9	54.3	+ 6.6
11–9–49	57.8	54.6	+ 5.9
12–21–49	56.5	53.2	+ 6.2
2–3–50	33.2	49.2	−32.6
3–29–50	32.6	49.1	−33.6
6–9–50	41.6	46.9	−11.3
8–11–50	44.9	43.2	+ 3.4
10–13–50	53.2	49.2	+ 8.1

plants in the plot, continued for approximately 5 months. By June 9, 1950 (7 months after the final application), the reduction was only 11 percent, and within another 2 months (9 months after treatment) the trees in the sprayed block were again as tall as trees having received no 2,4-D.

A similar response was detected in the diameter of trees (measured near the apex of the pseudostem). After the application of the first five doses of 2,4-D, no reduction was evident, and after the application of 104 ppm, a decided reduction (39 percent) occurred. The data in table 4 illustrate the recovery of tree vigor, as determined by diameter of the bole, by the end of the 9th month after the final treatment.

No difference in the average number of leaves was found between treated and untreated plants at any time during the test, although, in the case of young, distorted suckers, reduced numbers of leaves were recorded.

Influence on Yield. Particular effort was made to determine whether any of the quantities of 2,4-D used in the test influenced the number of bunches produced or the total yield of marketable fruit. The results are presented in table 5; the number of bunches, average weight of bunch, and total yield are given, by month, for both treated and untreated plots. These data show that from December 15, 1948, when the first application was made, to December 5, 1949, when the final application was made, there had been no depression in yield among treated trees. On the contrary, during this 12-month period in which 2.6, 5.1, 10.8, 10.8, and 10.8 ppm 2,4-D applications had been made, the treated trees produced, on a 100-clump basis, a total of 152 bunches with a combined weight of 7,702 pounds as compared with 125 bunches weighing 5,974 pounds produced by untreated trees. However, when a 104 ppm application was made (12–5–50), an immediate decline in yield of marketable fruit resulted. As discussed above, 89 percent of the sprayed trees and suckers were either killed outright or removed as a result of distortion of the new growth. Also, 85 percent of the bunches in existence at the time of spraying subsequently rotted or became so disfigured as to be unmarketable. Consequently, for 10 months following treatment, only 12 marketable bunches weighing 816 pounds were harvested from the treated plot (on a 100-clump basis), while a similar number of untreated trees yielded 128 bunches weighing 6,914 pounds. In October and November, 1950 — 11th and 12th month after treatment — the sprayed trees again started producing, and by December (13th month) the plot was, from all appearances, fully recovered.

Influence on Vegetative Reproduction. By making frequent comparisons between

TABLE 4. Average diameter of treated and untreated banana trees at intervals following the first application of 2,4-D

DATE	AVERAGE DIAMETER		REDUCTION IN DIAMETER
	Treated	Untreated	
			percent
12–13–48	4.9	5.0	− 2.0
2–18–49	4.9	4.8	+ 2.1
7–7–49	5.6	5.6	0.0
9–12–49	5.7	5.7	0.0
11–9–49	5.7	5.6	+ 1.8
12–21–49	5.8	5.7	+ 1.8
2–3–50	3.3	5.4	−38.9
3–29–50	3.3	5.3	−37.7
6–9–50	4.6	5.3	−13.2
8–11–50	5.2	5.2	0.0
10–13–50	5.5	5.4	+ 1.8

TABLE 5. Number of bunches produced, average bunch weight, and total yield of untreated bananas as compared with bananas sprayed with various concentrations of 2,4-D. All data have been corrected on the basis of 100 clumps

SPRAYING DATES	HARVEST DATES	TREATED					UNTREATED				
		Bunches		Average weight	Yield		Bunches		Average weight	Yield	
		number	*accumu-lative*	*per bunch*	*per month*	*accumu-lative*	*number*	*accumu-lative*	*per bunch*	*per month*	*accumu-lative*
12–15–48	December 1948	8	8	47.0	376	376	0	0	——	——	——
(2.6 ppm)	January 1949	16	24	57.5	920	1,296	25	25	56.3	1,408	1,408
2–16–49	February 1949	26	50	55.7	1,450	2,746	9	34	50.0	450	1,858
(5.1 ppm)	March 1949	22	72	48.0	1,054	3,800	20	54	45.6	913	2,771
	April 1949	10	82	34.0	340	4,140	15	69	40.9	614	3,385
	May 1949	8	90	40.5	324	4,464	7	76	38.1	267	3,652
	June 1949	6	96	39.7	238	4,702	6	82	40.5	243	3,895
7–7–49	July 1949	4	100	40.5	162	4,864	7	89	43.6	305	4,200
(10.8 ppm)	August 1949	16	116	45.6	730	4,594	11	100	42.2	464	4,664
	September 1949	8	124	50.0	400	4,994	4	104	50.8	203	4,867
10–3 and 10–12–49	October 1949	8	132	52.0	416	6,410	8	112	56.2	450	5,317
(10.8 ppm)	November 1949	20	152	64.6	1,292	7,702	13	125	50.5	657	5,974
12–5–49	December 1949	2	154	70.0	140	7,842	7	132	67.4	472	6,446
(104 ppm)	January 1950	8	162	65.8	526	8,368	5	137	55.4	277	6,723
	February 1950	2	164	75.0	150	8,518	11	148	60.9	670	7,393
	March 1950	0	164	——	0	8,518	23	171	62.2	1,430	8,823
	April 1950	0	164	——	0	8,518	26	197	53.0	1,378	10,201
	May 1950	0	164	——	0	8,518	6	203	50.2	301	10,502
	June 1950	0	164	——	0	8,518	17	220	51.0	867	11,369
	July 1950	0	164	——	0	8,518	15	235	43.2	648	12,017
	August 1950	0	164	——	0	8,518	10	245	49.0	490	12,507
	September 1950	0	164	——	0	8,518	8	253	47.6	381	12,888
	October 1950	6	170	44.3	266	8,784	12	265	45.9	551	13,439
	November 1950	6	176	52.0	312	9,096	16	281	54.2	866	14,305
	December 1950	18	194	50.5	909	10,005	12	293	57.4	688	14,993

the emergence and behavior of suckers in treated and untreated portions of the field, it was possible to determine whether certain small doses of 2,4-D influenced the reproduction of bananas. In these tests, 2.6, 5.1, 10.8, 10.8, and 10.8 ppm applications were observed to have no effect on reproduction. During the 12 months in which the applications were made, bimonthly counts of suckers (from 12 to 40 inches tall) were virtually the same for both plots. These counts were as follows: untreated, 171, 186, 105, 66, 29, and 37; treated (on a 100-clump basis), 172, 192, 98, 68, 24, and 42 plants. At bimonthly intervals untreated suckers, 12 to 40 inches in height, were 20.9, 25.8, 22.8, 30.4, 31.5, and 21.3 inches. Corresponding heights of treated suckers were 22.8, 26.4, 22.8, 30.4, 32.4, and 22.7 inches. During this period, 361 new suckers developed from 100 untreated clumps, while 176 new suckers developed from 50 treated clumps. No form of plant deformation, except the midvein russeting described elsewhere in this report, could be ascribed to these quantities of 2,4-D.

Unlike the lower doses, 104 ppm brought about changes both in the rate of sucker emergence and in sucker behavior. During the first 7 months after treatment, 318 suckers emerged from the 50 sprayed clumps (636 on a 100-clump basis), of which 83 (26.1 percent) either died because of cracking and buckling of the pseudostem or were removed because of distortion of the plant. During the same period, 248 suckers emerged from 100 untreated clumps, but not one of them died or was removed because of abnormality. These data reveal that 104 ppm 2,4-D, while leading to death or distortion of about 26 percent of the suckers emerging soon after treatment, greatly stimulated the rate of sucker production.

To determine whether the suckers arising from clumps exposed to 104 ppm 2,4-D were suitable transplanting material, a number of plants of the size normally used for banana propagation in Hawaii were collected at intervals after exposure of the parent clump and transplanted at University Farm, Honolulu, where they were compared in growth habit to suckers taken from unexposed clumps. The transplanted suckers were selected in 10-plant units from among the following: (1) suckers measuring 12 inches high at the time of exposure, (2) suckers emerging 4 weeks after exposure, (3) suckers emerging 8 weeks after exposure, and (4) suckers emerging 12 weeks after exposure. The above-ground portions of the first group of 10 plants died soon after transplanting but not before new buds developed on 9 of the 10 corms involved. These buds subsequently developed, giving rise to normal plants which fruited approximately 6 months later than unexposed suckers transplanted at the same time. Four of the 10 suckers emerging from the soil 4 weeks after treatment died; the remainder survived and produced bunches on an average of 2 months later and 20 pounds lighter than untreated check plants. On the corms of the four dying plants, new buds were formed which later developed normally. All suckers emerging 8 and 12 weeks, respectively, after treatment survived and produced bunches. Bunches from the 8-week series tended to be somewhat smaller than bunches produced by unexposed suckers, but no such reduction was detected in the latter group.

DISCUSSION

In the foregoing pages it was pointed out that, although solutions containing between 2.5 and 5.0 ppm 2,4-D (applied at rates of 0.75 to 1.50 grams of free acid per acre) were sufficient to cause symptoms, on sensitive indicator plants, of about the same degree of severity as the symptoms found on the same species of plants in close proximity to sites of extensive 2,4-D usage, these dosages failed to produce a response among Cavendish bananas. It was further reported that, although bananas reacted mildly to three successive doses of 10.8 ppm 2,4-D (11.2 grams acid per acre), their reaction to a 104 ppm solution (91.8 grams per acre) involved a high incidence of plant mortality, fruit and plant distortion, fruit rot, decreased fruit production, and increased sucker production. These features raise the questions of (1) the degree to which symptoms observed in experimental plots and symptoms found on bananas grown in areas alleged to have received drifts of 2,4-D conformed, and (2) to what degree the higher dosage of 2,4-D (104 ppm; 91.8 grams free acid per acre) injured an assortment of broad-leaved plants.

During 1948–49, when extensive 2,4-D damage was reported from scattered points throughout the Islands, certain exposed areas were visited, and numerous banana plantings were examined. In addition, banana specimens were submitted from outlying areas. Among the specimens observed in the laboratory and in the field, many of the symptoms described above were noted. In plantings at Aiea, South Oahu, midvein russetting, finger distortion, and premature ripening of the fruit were found after local farmers had first reported extensive injury to various other fruit and vegetable crops. At Ewa, South Oahu, pseudostem cracking and toppling were found among wayside and dooryard plantings. For the most part, the bananas affected in this manner were located within a few hundred feet of fields where 2,4-D had been used. Banana specimens submitted from Pahala, East Hawaii, where extensive sugarcane culture and pasture improvement programs were under way, were characterized by the bumpy or lumpy appearance described earlier in the report. These fruits, although firm green when received, ripened and rotted a few days later. At no time during or preceding these studies, however, did the writer observe as extensive a killing of plants or as decided a reduction in crop yield as those prevailing in experimental plots sprayed with a 104 ppm solution (91.8 grams per acre) of 2,4-D.

It was stated previously in this bulletin that a number of species of 2,4-D sensitive plants (tomatoes, beans, peppers, hibiscus, cotton, and papayas) were interspersed among the treated banana clumps at the time of each 2,4-D application. Some of them were left to become exposed through chance and others were deliberately sprayed with the same solution as was applied to the bananas. In addition, other plants occurring as weeds in the field were sprayed with 2,4-D. Such plants included Flora's paintbrush (*Emilia sonchifolia*), Spanish-needle (*Bidens pilosa*), Crotalaria (*Crotalaria Saltiana*), annual sow-thistle (*Sonchus oleraceus*), woodsorrel (*Oxalis Martiana*), and false mallow (*Malvastrum coromandelianum*). All these plants, and many of those exposed through chance, exhibited 2,4-D symptoms — some of them severely so. In the most severe cases (usually tomatoes, beans, cotton, and peppers) stem lesions accompanied stem deformation and/or defoliation. Although no outright killing occurred, a small number of the more severely injured plants died a few weeks later. In comparing the symptoms produced by these plants with symptoms observed on plants grown in 2,4-D exposed areas, the severity of the former was without exception greater than that observed among the latter, on an average basis.